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SIMPLEX 'A' - A SIMPLIFIED ATMOSPHERIC DISPERSION MODEL FOR AIR--ETC(U)
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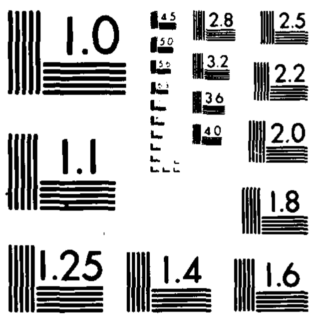

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LEVEL II (13) FAA-EE-81-8

Simplex "A" -A Simplified Atmospheric Dispersion Model for Airport Use-(Users Guide)

U.S. Department of Transportation
Federal Aviation Administration

Office of Environment and Energy
Washington, D.C. 20591

July 1981

H. M. Segal

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16. Abstract

The method, limitations and uses of the SIMPLEX "A" atmospheric dispersion model are described. The model determines pollutant concentrations from taking-off aircraft and has the flexibility to easily accept parameter changes. It can treat either single or multiple aircraft departures and permits air quality calculations to be made by persons without an extensive computer background. The program is listed and the results of two sample problems are given to illustrate the use of the model.

This is a research model with many of its dispersion and turbulence parameters still under investigation. As such it has not been adopted by the FAA for formalized pollution assessments.

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A

INTRODUCTION

Atmospheric dispersion models are mathematical expressions that combine source emissions with meteorological parameters to produce air quality estimates at specified receptor locations. At airports where many sources and receptors are involved, refined models such as the Airport Vicinity Air Pollution model (AVAP)(1) are used to determine air quality. However, where few sources and receptors are involved, screening models are very attractive for identiving the need for further analysis with the more refined models. This report describes one of these screening models, SIMPLEX "A".

This report describes the mathematical basis for the model, lists the program, and explains the steps taken to compute pollution dosage. Special program features are described and two sample problems are solved.

The experienced user, who is primarily concerned with running a specific problem, may bypass the descriptive sections of this report and proceed directly to the "Sample Problem-Program Operation" section on page 5.

MODEL DESCRIPTION

SIMPLEX "A", which has been programmed for the Hewlett Packard 67 and 97 desk calculators, addresses emissions during takeoff. Additional SIMPLEX models are being developed to determine the air quality impact from taxiing and queueing aircraft as well as from ground vehicles at the airport. The model is particularly useful at small airports and at those airports having only a few dominant sources.

SIMPLEX "A" uses the same Gaussian formulation employed in many of the refined models listed in the Environmental Protection Agency's (EPA) guidelines on air quality models. It accomplishes its function by simplifying many of the detailed features of the more refined models. The model is an integrated puff model for an accelerating point source. Downwind receptors are assumed to be at ground level (z=0) and receive pollution doses from each emission puff. Figure 1 describes the source-receptor geometry where the dose from each emission puff is summed at a receptor to give a total dose due to a complete takeoff event. Concentrations are measured in parts per million (ppm) of Nitrogen Dioxide (NO_2) where the complete conversion of Nitrogen Oxides (NO_x) to NO_2 is assumed. In cases where Carbon Monoxide (CO) concentrations are required, NO_2 calculations can be factored appropriately. The total dose at point x,y,0 is given by the equation:

1 $$\psi' = \frac{G}{\pi \sigma_{z_T} \sigma_{y_T} U} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_{z_T}}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{Y}{\sigma_{y_T}}\right)^2\right] \qquad (2)$$

SYMBOL	DEFINITION	UNITS
ψ' =	receptor exposure of dose	ppm-sec. (NO_2)
x =	downwind distance in the direction of the mean wind	meters (m)
Y =	crosswind distance	m

z - height above ground level — m

σ_{z_T} = standard deviation of plume concentration in the vertical direction — m

σ_{y_T} = standard deviation of plume concentration in the crosswind direction — m

U - wind speed — m/sec

Q_T = total emissions during an emission release — grams

H = effective height of emissions — m

The program is printed out in Figure 2. The registers, labels, inputs and outputs are listed in Figures 3 and 4.

SPECIAL PROGRAM FEATURES

Standard Deviations of Plume Concentration (sigma (σ))

A subprogram was employed to determine the standard deviation of plume concentration in the horizontal (crosswind) and vertical directions. This subprogram was based upon the assumption that pollution disperses according to the power law expression:

2 $$\sigma = Kx^b \quad \text{or, in straight line form}$$

3 $$\text{Log}\,\sigma = b\,\text{Log}\,x + \text{Log}\,K$$

The exponent "b" governs the rate of pollutant dispersion and the coefficient "K" depends upon atmospheric stability.

Analysis of the Pasquill/Gifford curves* (3) used in most dispersion models shows that for stability classes "B" through "E", single straight lines are approximated when σy and σz values are plotted logarithmically against downwind distance up to a source-receptor distance of 1000 meters. It is also seen that these straight lines have the same slope.

With the realization that σ as a function of four stability classes can be represented as single straight lines with the same slope (0.9), equation 2 can be rewritten as:

4 $$\sigma y = K_1 x^{0.9}$$

5 $$\sigma z = K_2 x^{0.9} \quad \text{when x does not exceed 1000 meters}$$

The values of K_1 and K_2 which are listed in the program printout (Figure 2) were obtained by solving equations 4 and 5 for K_1 and K_2 after substituting values for x, σy and σz.

The program not only allows for calculation of the σy and σz values in equations 4 and 5 but also has provisions to input values for initial sigmas (σo_z and σo_y) in order to account for the enhanced dispersion caused by the hot, high velocity jet exhaust. (This enhanced dispersion is discussed in (4), (5) and (6)). The final dispersion parameter (σT) is automatically calculated in the program by summing and squaring initial and calculated σ's and then extracting the square root.

---

* The values from the Pasquill/Gifford curves were used per se and were not adjusted for averaging times different from those stated in (3).

Because of technical difficulties, it has not been possible to determine σ_o values from measurements taken at airports during high thrust airplane takeoff. However, plume measurements have been made during low thrust operations at Dulles (4) and Los Angeles International (7) airports. Average values from measurements taken at these two airports (8 meters for σ_{o_z} and 16 meters for σ_{o_y}) are incorporated in the model.

Plume Height

Because of the lack of experimental data to support plume rise theories for taking-off aircraft, special plume rise algorithms have not been incorporated into the model. While research is planned in this area, until this research is completed, it was assumed that the plume height was at least as high as the airplane engines. An average value for this parameter is four meters for airplanes operatng at a typical large airport.

Stability Class

Pasquill/Gifford stability classes "B", "C", "D", and "E" are expected to prevail at the airport during the times of air quality assessment. Turner (3) gives a detailed description of the characteristics of each stability class. A particular stability class is identified by a range of wind speed, solar radiation intensity, and cloud cover. Values for these parameters can be obtained from local National Weather Service or observer personnel.

Winds

The coordinate system is oriented to the runway on which the aircraft are assumed to be operating. Since aircraft usually take off into the wind, wind angles are measured only from 0 to 90 degrees on either side of the runway. For example, a zero degree wind would blow directly down the runway; a 90 degree wind would blow perpendicular to the runway.

Acceleration

Aircraft performance manuals can be used to determine acceleration during takeoff. However, the program has been structured to accept an average takeoff acceleration and performance information should be adjusted to average acceleration values.

Emission Tail

During the operation of a jet engine, the high velocity of its exhaust gases creates an emission tail which can extend for a considerable distance behind the aircraft (Figure 5). This tail is simulated by assuming a value for its length and by assuming a finite number of points along the tail at which emissions are considered to be released. Observations of the tail length of a number of aircraft enabled the estimation of a nominal value for this tail length and parametric calculation of concentrations at receptors enabled the selection of a minimum number of emission release points that would provide reasonable model accuracy for those wind angles that permit a sweep of pollution over a receptor during the takeoff run.

The program assumes a 225 meter emission tail with three emission release points located 75 meters apart in the tail (see Figure 5). The model is programmed to index the emission starting point 75 meters further down the tail after each iteration sequence is completed. The first and last points in the tail are 37.5 meters from the ends of the tail. (The tail starts at the exit plane of the engine.)

Vertical Dispersion Lid

Calculations under a variety of assessment conditions showed that a lid on vertical dispersion, i.e. an inversion "cap", had an insignificant effect on concentration at the short downwind distances (less than 1000 meters) employed in assessing aircraft pollutant impact. An algorithm to account for this phenominon is, therefore, not included in the program.

Iteration Interval

From past program use, a one-second iteration time is recommended. Using this iteration time interval, the dose calculation can be completed in less than 15 minutes at a source receptor distance of 300 meters.

Dosage Output

Total dosage is printed out at the end of each iteration sequence. The program is stopped when the dosage reaches a maximum value. Output units are parts per million-seconds (ppm-seconds). To determine the average concentration over a one-hour time period (for compatability with a particular short term standard) the dosage must be divided by 3600 seconds.

SAMPLE PROBLEM

The step by step procedure for solving the sample problems is described in this section. While this procedure is structured for a single aircraft, the same procedure can be used for any number of aircraft by treating them as one large aircraft.

Preparation of Data For Program Execution

From Figure 1 it is seen that the Case 1 receptor is located 337.5 meters downwind from the aircraft (as measured along the runway) and 200 meters abeam of the runway centerline. The Case 2 receptor is located 262.5 meters upwind of the aircraft and 100 meters abeam to it.

The objective of this problem is to determine the air quality impact of 747 NO_x emissions (reported as NO_2) during takeoff. During this takeoff, it was assumed that a 5-meter per second wind was blowing at 30 degrees to the runway centerline and that Pasquill/Gifford stability class "E" prevailed. The 747 was assumed to have a constant takeoff acceleration of 1.3 meters per second per second. All imputs are listed in Figures 6 and 7.

The following procedure was used in solving the problems:
Source emissions were obtained from AP-42 supplement 10 (8), where 747 NO_x emissions are listed at 215.3 kilograms per hour per engine or 60 grams per second per engine. Since the 747 has four engines, the total emission rate was 240 grams per second. To accommodate the three emission release points in the "tail" (see Figure 5) this rate was divided by 3 to reduce its value to 80 grams per second per "tail" release point. Selecting an iteration time of one second and multiplying it by the emission rate results in the release of 80 grams of NO_x per puff.

σo_z and σo_y values of 8 and 16 meters respectively were selected from the Standard Deviation of Plume Concentration section of this report and a plume height of 4 meters was selected from the plume height section. The beginning time was set at zero by inputting the iteration time (one second) and assigning a negative sign to it. The Case 1 receptor is downwind of the aircraft giving it a positive sign (see Figure 1). The Case 2 receptor is upwind of the aircraft giving it a negative sign. The airplane to receptor distance is converted to a "tail" to receptor distance (at the first "tail" emission point, see Figure 5) by subtracting 37.5 meters from the former to uniformly space the three tail release points over the 225 meter tail length. The resulting distance between the receptors and the first point in the emission tail is +300 meters for Case 1 and -300 meters for Case 2.

Program Operation

Load the Program

Before loading the program the "on-off" switch should be in the "on" position and the "run-program" switch should be in the "run" position (for the HP-97 the "trace-manual-norm" switch should be in the "manual" position). The program can then be loaded into the calculator by first pushing the number 1 end of the magnetic tape strip* into the slot in the upper left hand portion of the HP-97 calculator. (On the HP-67 calculator the slot is located on the right hand side.) When the strip comes out the other side, turn it around to the number 2 end and push it through the slot a second time. The program is now loaded into the calculator and the tape strip which has come out the back of the calculator can be stored in the horizontal slot just under the calculator switches.

Input Data

Inputs for the Case 1 and Case 2 problems are listed in Figures 6 and 7 and a printout of the results is listed in Figures 8 and 9. The Case 1 problem is solved by first entering the values for the six input parameters listed in Figure 6 into the Primary Register by depressing the following keys: 80 STO 0 8 STO 2 4 STO B 30 STO D 1 STO E 5 STO I. Any input errors can be erased by depressing the CLx key or by turning off the calculator, restarting it and reloading the program.

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* This tape strip can be obtained by contacting the Federal Aviation Administration; Office of Environment and Energy; 800 Independence Avenue S.W.; Washington, D.C.20591

After the primary register has been loaded the secondary register is loaded by depressing the following keys: "f" "P-S"* 300 STO 0 200 STO 4 16 STO 6 1 CHS** ATO 7 1.3 STO 8 "f" "P-S*.

Program Execution

The program is started by depressing the "E" key for the assumed "E" stability (The "B", "C", and "D" keys will start the program for "B", "C", and "D" stability classes respectively). The resulting three numbers printed out on the HP-97 or displayed on the HP-67 after each iteration is completed are; (1) time (in seconds) from the program start; (2) distance (in meters) that the point in the emission tail has moved down the runway; and (3) total dose (in ppm-seconds) that the receptor has received.

It is noted that after 20 iterations, the dose value will reach a maximum of 82.16 ppm-sec. This value represents the dose received at the receptor from the first emission release point in the "tail". When the dose converges on this maximum value (when all concentration digits remained unchanged out to the second decimal point) the R/S key is depressed to stop the program. The "A" key is then depressed to clear registers and index the starting point to the second tail position. The "E" key is then depressed a second time to start the next computation. Again when the dose value levels off at 55.59 ppm-sec., the "R/S" key is depressed to stop the program. Depressing the "A" key and then, after the display stops flashing, the "E" key, permits the last computation to be completed which results in a dosage of 40.85 ppm-sec. for the last tail point. After reaching this last convergence value, the program is terminated by depressing the R/S key. The person making the calculation can then sum the three dose values and divide them by 3600 to produce a one-hour concentration of 0.05 ppm.

CONCLUSIONS

The method, limitations and use of the SIMPLEX"A" model have been described. The program can determine concentrations from departing aircraft and has the flexibility to easily accept parameter changes. It can treat either single or multiple events and permits air quality calculations to be made by persons without an extensive computer background. The model can assist in determining the impact of aircraft emissions on air quality in conjunction with requirements for controlling engine emissions and can be used as a screening tool in evaluating the air quality impact of proposed Federal actions at airports.

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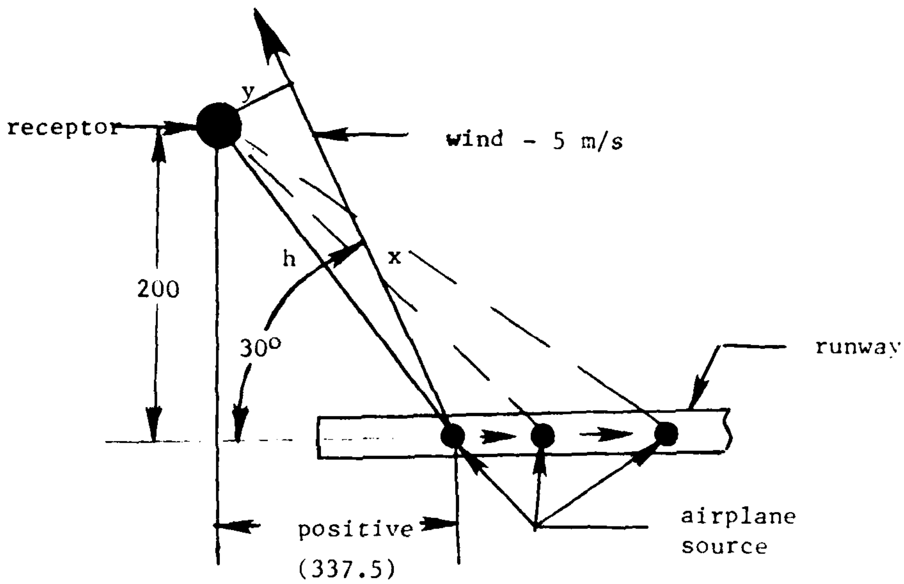
* The P-S command is input by depressing the "CLx" key on the HP-97 and the "CHI" key on the HP-67 calculator.

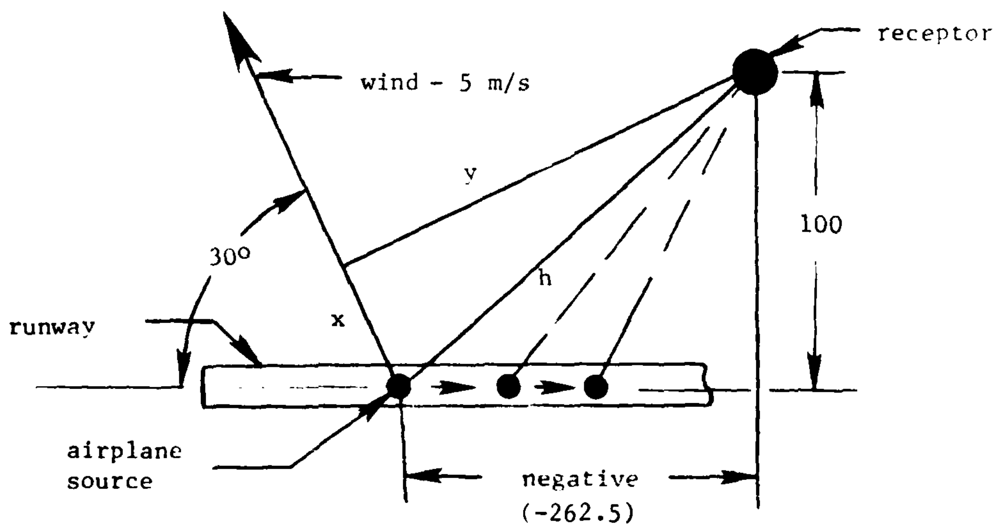
** Negative numbers are entered into the Hewlett Packard calculators by depressing the appropriate number key followed by the "CHS" key.

Figure 1

SOURCE-RECEPTOR GEOMETRY DURING TAKEOFF



Case 1



Case 2

Figure 2

PROGRAM PRINTOUT

Clears registers and provides input data to start new iteration sequence.

```
*LBLA
RCL3
X=0?
P⇄S
RCL0
X≠0?
GTO5
GTO6
*LBL4
0
STO2
RCLE
CHS
STO7
P⇄S
R/S
```

Stores meteorological exponents and coefficients for stability classes "B" thru "E".

```
*LBLB
.
9
STO4
STO6
.
1
7
STO5
.
3
0
STO7
GTO8
*LBLC
.
9
STO4
STO6
.
1
2
STO5
.
2
0
STO7
GTO8
*LBLD
.
3
STO4
STO6
.
0
7
STO5
.
1
3
STO7
GTO8
*LBLE
.
3
STO4
STO6
.
0
5
4
STO5
.
1
STO7
GTO6
```

Adds iteration time to total time and stores.

```
*LBL8
P⇄S
RCL8
RCL7
RCLE
+
STO7
```

Moves airplane to new location in accordance with time and acceleration values.

```
SPC
PRTX
X²
RCL8
x
2
÷
+
STO5
PRTX
```

Performs trigonometric calculation to obtain hypotenuse "h" (see Figure 1)

```
X²
RCL4
X²
+
√X
STO9
```

Iteration By Pass

```
RCL4
RCL5
X=0?
GTO7
```

```
÷
TAN⁻¹
X<0?
GSB9
RCLD
-
X<0?
CHS
COS
X<0?
GTO7
RCL9
×
P⇄S
STO1
```

Performs trigonometric calculation to determine "x" distance.

```
X²
CHS
P⇄S
RCL9
X²
+
√X
STOC
P⇄S
```

Performs trigonometric calculation to determine "y" distance.

```
RCLI
RCL3
+
STO8
RCL8
RCL4
Yˣ
RCL5
×
X²
STO9
RCL2
X²
+
√X
STO9
```

Performs calculation to determine final sigma "z" (initial plus distance-related sigma's).

```
RCL8
RCL6
Yˣ
RCL7
×
X²
STOA
P⇄S
RCL6
X²
P⇄S
+
√X
STOA
```

Performs calculation to determine final sigma "y".

```
RCLB
RCL9
÷
X²
.
5
CHS
×
eˣ
P⇄S
STO1
```

Determines value for plume height function.

```
RCLC
RCLA
÷
X²
.
5
CHS
×
eˣ
STO3
```

Determines value of crosswind function.

```
P⇄S
RCL8
Pi
÷
RCLA
÷
RCL9
÷
RCLI
÷
.
0
0
1
3
÷
```

Performs dose calculation.

```
P⇄S
RCL1
×
RCL3
×
RCL2
+
STO2
```

Determines final dose corrected for plume height and crosswind distances and adds to previous dose sum.

```
PRTX
```

Prints total dose.

```
P⇄S
GTO8
*LBL9
1
8
0
+
RTN
*LBL7
P⇄S
GTO8
*LBL5
7
5
-
STO0
GTO4
*LBL6
7
5
-
STO0
GTO4
R/S
```

Miscellaneous Subroutines

Figure 3

REGISTERS AND LABELS

REGISTERS

Primary

0 emission rate
1 "x" distance
2 initial sigma "z"
3 zero register
4 sigma "z" exponent
5 sigma "y" coefficient
6 sigma "y" exponent
7 sigma "z" coefficient
8 total distance (1+3)
9 sigma "z"
A sigma "y"
B plume height
C "y" distance
D wind angle
E iteration time
I wind velocity

Secondary

0 fixed source receptor distance along runway
1 plume rise factor
2 dose summation
3 sidewind "y" factor
4 fixed distance -receptor to runway
5 variable distance between source and receptor in the runway direction
6 initial sigma "y"
7 time at runway location
8 acceleration
9 hypotenuse ("h" in Figure 2)

LABELS

A program to clear registers and make required inputs for new iteration sequence
B,C,D,E, Storage of coefficients and exponents for sigma calculations - stability classes B,C,D,and E
4 subroutine for Label A
5 subroutine for Label A
6 subroutine for Label A
7 subroutine to switch registers
8 main program to move airplane along runway and to calculate dosage
9 subroutine of Label 8

Figure 4

INPUTS and OUTPUTS

INPUTS

Item	Units	Keys
Primary Register (P)		
source emissions over duration of event- emission rate x iteration time	grams	Sto 0
initial sigma "z"	meters	Sto 2
plume height	meters	Sto B
wind angle	degrees	Sto D
iteration interval	seconds	Sto E
wind velocity	meters per second	Sto I
Secondary Register		
fixed source receptor distance along runway	meters	Sto 0
fixed distance from receptor to runway	meters	Sto 4
initial sigma "y"	meters	Sto 6
beginning time	seconds	Sto 7
acceleration	meters/sec/sec	Sto 8

OUTPUTS

total elapsed time at iteration	seconds	Prnt 7
fixed source-receptor distance along runway	meters	Prnt 0
dose sum	parts per million sec.	Prnt 2

Figure 5

EMISSION TAIL GEOMETRY

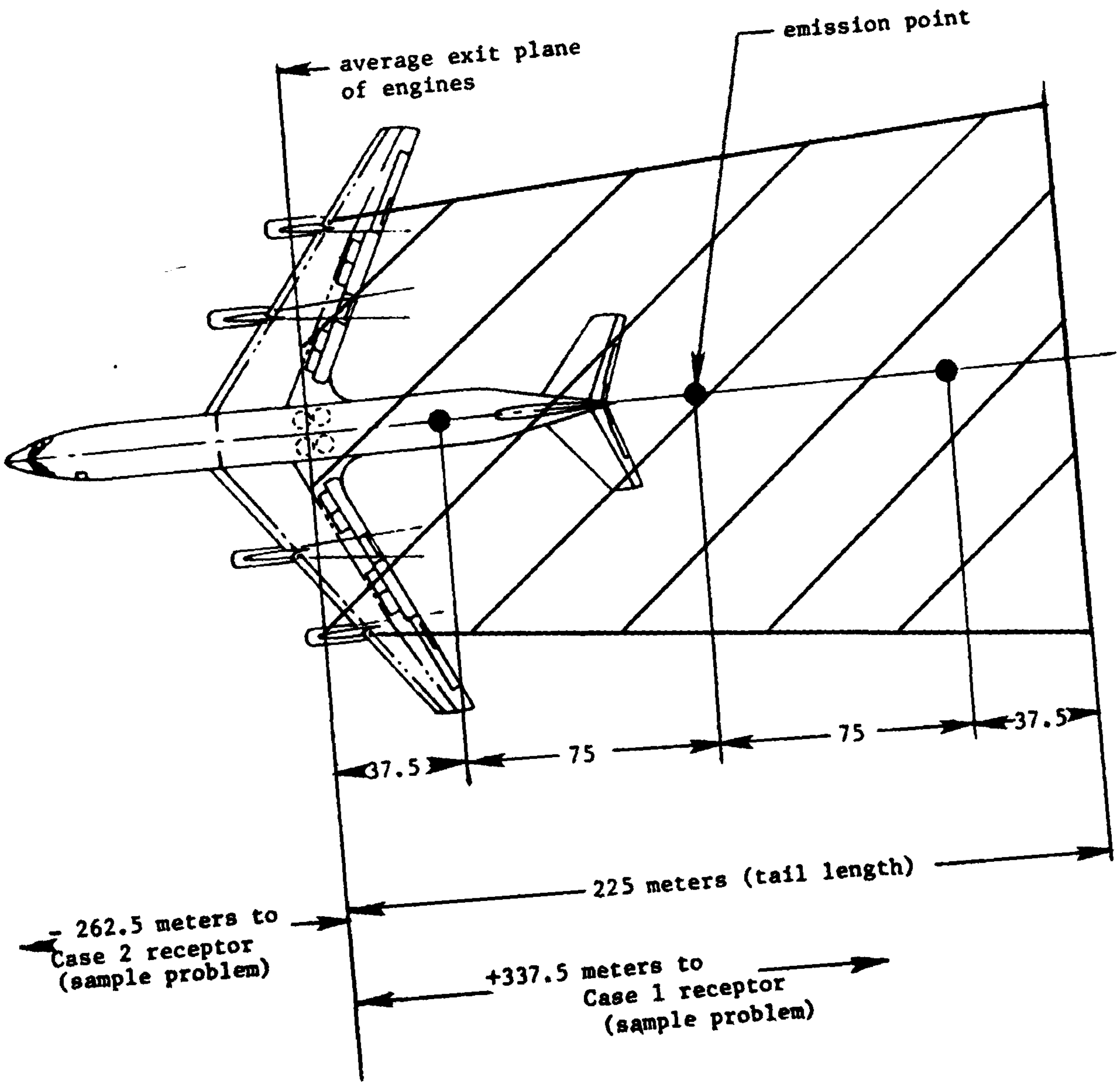


Figure 6

SAMPLE PROBLEM INPUTS - Case 1

INPUTS

Item	No./ Units		Keys*
Address Primary Register			none
source emissions **over duration of event (emiss. rate x iter. time) (80 gm/s x 1 sec.)	80	grams	Sto 0
initial sigma "z"	8	meters	Sto 2
plume height	4	meters	Sto B
wind angle	30	degrees	Sto D
iteration interval	1	second	Sto E
wind velocity	5	meters per second	Sto I
Address Secondary Register			f, P-S
fixed source receptor distance along runway	+300	meters	Sto 0
fixed distance from receptor to runway	200	meters	Sto 4
initial sigma "y"	16	meters	Sto 6
beginning time ***	-1	second	Sto 7
acceleration ****	1.3	meters/sec/sec	Sto 8
Readdress Primary Register			f, P-S

* Applicable to both HP-97 and HP-67 calculators except that the wind velocity is loaded into the HP-67 calculator by depressing the black "h" key followed by the black lettered "ST I" key.

** Possible data source - (7).

*** For a beginning time of zero, the negative value of the iterative duration must be input. This is accomplished by entering the duration value followed by the "CHS" key.

**** Possible data source - Aircraft Performance Manuals.

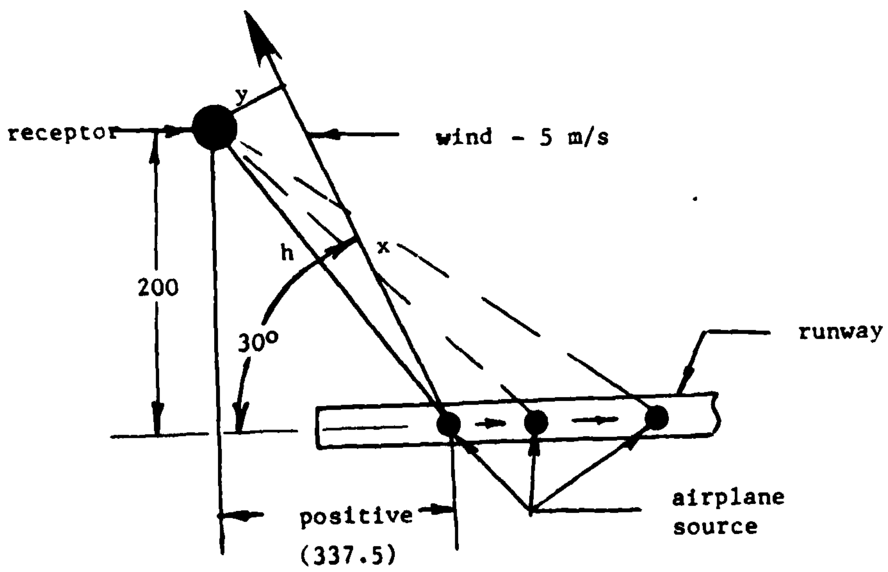


Figure 7

SAMPLE PROBLEM INPUTS - Case 2

INPUTS

Item	No./ Units		Keys*
Address Primary Register			none
source emissions **over duration of event (emiss. rate x iter. time) (80 gm/s x 1 sec.)	80	grams	Sto 0
initial sigma "z"	8	meters	Sto 2
plume height	4	meters	Sto B
wind angle	30	degrees	Sto D
iteration interval	1	seconds	Sto E
wind velocity	5	meters per second	Sto I
Address Secondary Register			f, P-S
fixed source receptor distance along runway	-300	meters	Sto 0
fixed distance from receptor to runway	100	meters	Sto 4
initial sigma "y"	16	meters	Sto 6
beginning time ***	-1	seconds	Sto 7
acceleration ****	1.3	meters/sec/sec	Sto 8
Readdress Primary Register			f, P-S

* Applicable to both HP-97 and HP-67 calculators except that the wind velocity is loaded into the HP-67 calculator by depressing the black "h" key followed by the black lettered "ST I" key.

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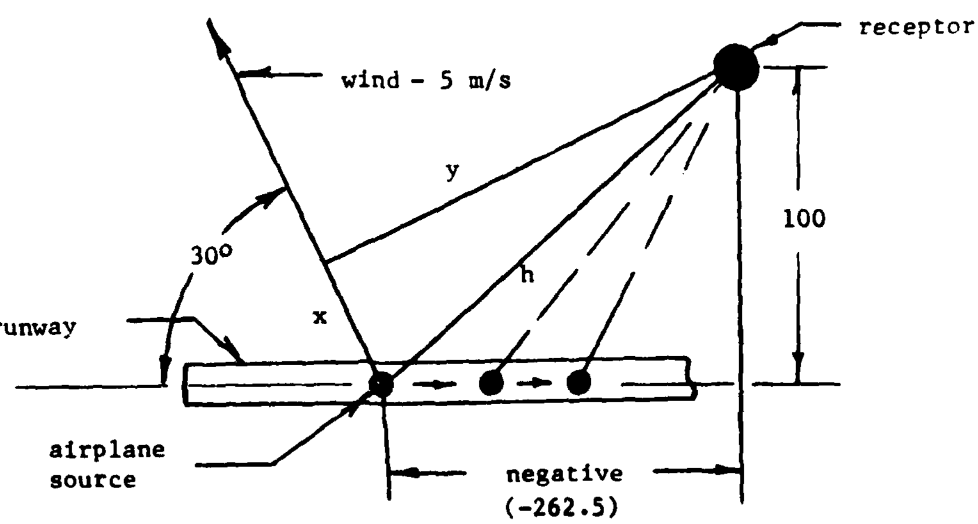

Figure 8

RESULTS - Case 1

Primary Register

33.00	0
0.00	1
0.00	2
0.00	3
0.00	4
0.00	5
0.00	6
0.00	7
0.00	8
0.00	9
0.00	A
4.00	B
0.00	C
70.00	D
1.00	E
5.00	F

Secondary Register

300.00	0
0.00	1
0.00	2
0.00	3
200.00	4
0.00	5
15.00	6
-1.00	7
0.00	8
0.00	9
0.00	A
4.00	B
0.00	C
70.00	D
1.00	E
5.00	F

<u>**Start First Iteration**</u>

time	0.00	***
distance	300.00	***
dose	4.35	***
	1.00	***
	300.65	***
	9.34	***
	2.00	***
	301.50	***
	15.13	***
	3.00	***
	305.25	***
	20.45	***
	4.00	***
	310.40	***
	25.30	***
	5.00	***
	315.25	***
	31.20	***
	6.00	***
	320.40	***
	38.05	***
	7.00	***
	331.85	***
	45.17	***
	8.00	***
	341.00	***
	51.85	***
	9.00	***
	351.65	***
	58.47	***
	10.00	***
	365.00	***
	64.40	***
	11.00	***
	377.65	***
	70.50	***
	12.00	***
	390.00	***
	73.34	***
	13.00	***
	403.85	***
	77.60	***
	14.00	***
	427.40	***
	79.21	***
	15.00	***
	445.25	***
	80.50	***
	16.00	***
	460.40	***
	81.43	***
	17.00	***
	487.85	***
	81.77	***
	18.00	***
	513.00	***
	82.07	***
	19.00	***
	534.85	***
	82.12	***
	20.00	***
	557.60	***
	82.15	***

<u>**Start Second Iteration**</u>

time	0.00	***
distance	225.00	***
dose	0.00	***
	1.00	***
	225.85	***
	0.50	***
	2.00	***
	227.60	***
	0.80	***
	3.00	***
	231.85	***
	1.35	***
	4.00	***
	235.40	***
	1.85	***
	5.00	***
	241.25	***
	2.50	***
	6.00	***
	248.40	***
	7.00	***

Figure 8 (CONT.)

7.00 ***
253.25 ***
5.15 ***

8.00 ***
2[illegible] ***
7.30 ***

9.00 ***
2[illegible].25 ***
10.75 ***

10.00 ***
2[illegible] ***
14.45 ***

11.00 ***
3[illegible].25 ***
19.59 ***

12.00 ***
3[illegible].60 ***
25.27 ***

13.00 ***
374.25 ***
31.54 ***

14.00 ***
353.40 ***
39.07 ***

15.00 ***
3[illegible].25 ***
41.33 ***

16.00 ***
351.40 ***
43.34 ***

17.00 ***
411.25 ***
50.27 ***

18.00 ***
475.60 ***
57.05 ***

19.00 ***
455.25 ***
54.92 ***

20.00 ***
475.00 ***
55.23 ***

21.00 ***
5[illegible].25 ***
55.42 ***

22.00 ***
5[illegible].60 ***
55.53 ***

23.00 ***
5[illegible].25 ***
55.53 ***

24.00 ***
533.40 ***
55.53 ***

25.00 ***
571.25 ***
55.53 ***

26.00 ***
564.40 ***
55.53 ***

27.00 ***
5[illegible].25 ***
55.53 ***

28.00 ***
734.50 ***
55.53 ***

29.00 ***
7[illegible].25 ***
55.53 ***

30.00 ***
[illegible] ***
55.50 ***

31.00 ***
543.65 ***
55.53 ***

32.00 ***
5[illegible].53 ***
55.53 ***

33.00 ***
5[illegible].25 ***
55.53 ***

34.00 ***
5[illegible].40 ***
55.50 ***

Start Third Iteration

time 0.00 ***
distance 150.00 ***
dose 1.[illegible] ***

1.00 ***
150.25 ***
3.50699[illegible]E-0[illegible] ***

2.00 ***
151.60 ***
5.5129[illegible]E-04 ***

3.00 ***
155.25 ***
9.55[illegible]E-04 ***

4.00 ***
15[illegible].40 ***
1.644[illegible]E-03 ***

5.00 ***
1[illegible].25 ***
3.055[illegible]E-03 ***

6.00 ***
173.40 ***
0.01 ***

7.00 ***
181.25 ***
0.01 ***

8.00 ***
191.60 ***
0.04 ***

9.00 ***
201.65 ***
0.05 ***

10.00 ***
215.00 ***
0.24 ***

11.00 ***
229.65 ***
0.50 ***

Figure 8 (CONT.)

12.00 ***
243.60 ***
1.43 ***

13.00 ***
257.85 ***
7.12 ***

14.00 ***
277.40 ***
8.17 ***

15.00 ***
286.25 ***
13.77 ***

16.00 ***
315.40 ***
18.24 ***

17.00 ***
337.35 ***
22.53 ***

18.00 ***
362.60 ***
23.73 ***

19.00 ***
384.65 ***
34.53 ***

20.00 ***
410.00 ***
37.70 ***

21.00 ***
435.65 ***
35.45 ***

22.00 ***
464.60 ***
43.31 ***

23.00 ***
487.85 ***
43.53 ***

24.00 ***
514.40 ***
43.73 ***

25.00 ***
553.25 ***
43.83 ***

26.00 ***
585.40 ***
43.34 ***

27.00 ***
623.85 ***
43.75 ***

Figure 9

RESULTS - Case 2

```
20.00  0
 ?.?0  1
 ?.00  2
 ?.00  3
 ?.00  4
 ?.00  5
 0.00  6
 0.00  7
 ?.00  8
 ?.00  9
 ?.00  A
 4.00  B
 2.00  C
30.00  D
 1.00  E
 5.00  I

-300.00  0
   0.00  1
   0.00  2
   3.00  3
 100.00  4
   0.00  5
  16.00  6
  -1.00  7
   1.30  8
   0.00  9
   0.00  A
   4.00  B
   2.00  C
  30.00  D
   1.00  E
   5.00  I

   0.00  ***
-300.00  ***

   1.00  ***
-299.75  ***

   2.00  ***
-297.40  ***

   3.00  ***
-294.15  ***

   4.00  ***
-289.60  ***

   5.00  ***
-287.75  ***

   6.00  ***
-275.60  ***

   7.00  ***
-265.15  ***

   8.00  ***
-258.40  ***

   9.00  ***
-247.35  ***

  10.00  ***
-235.00  ***

  11.00  ***
-221.35  ***

  12.00  ***
-206.40  ***

  13.00  ***
-190.15  ***

  14.00  ***
-172.60  ***

  15.00  ***
-153.75  ***

  16.00  ***
-133.60  ***

  17.00  ***
-112.15  ***

  18.00  ***
 -89.40  ***

  19.00  ***
 -65.35  ***

  20.00  ***
 -40.00  ***
4.745???3?3-05  ***

  21.00  ***
 -13.35  ***
1.19?4?595?-06  ***

  22.00  ***
  14.60  ***
1.7?29?48??-04  ***

  23.00  ***
  47.85  ***
   ?.??  ***

  24.00  ***
  74.40  ***
   ?.?0  ***

  25.00  ***
 1??.25  ***
   ?.??  ***

  26.00  ***
 1??.40  ***
  ??.??  ***

  27.00  ***
 177.?5  ***
  ??.?0  ***

  28.00  ***
 2??.00  ***
  ??.??  ***

  29.00  ***
 24?.?5  ***
  34.24  ***

  30.00  ***
 2?5.?0  ***
  ??.?4  ***

  31.00  ***
 324.65  ***
  ??.??  ***

  32.00  ***
 365.60  ***
  ??.?1  ***
```

Figure 9 (CONT.)

```
       0.00  ***
    -375.00  ***

       1.00  ***
    -374.75  ***

       2.00  ***
    -372.40  ***

       3.00  ***
    -368.15  ***

       4.00  ***
    -364.00  ***

       5.00  ***
    -355.75  ***

       6.00  ***
    -351.00  ***

       7.00  ***
    -347.15  ***

       8.00  ***
    -337.40  ***

       9.00  ***
    -321.75  ***

      10.00  ***
    -312.00  ***

      11.00  ***
    -295.75  ***

      12.00  ***
    -281.40  ***

      13.00  ***
    -265.15  ***

      14.00  ***
    -247.60  ***

      15.00  ***
    -228.75  ***

      16.00  ***
    -208.00  ***

      17.00  ***
    -187.15  ***

      18.00  ***
    -164.40  ***
```

```
             19.00  ***
           -140.35  ***

             20.00  ***
           -115.00  ***

             21.00  ***
            -88.35  ***

             22.00  ***
            -60.40  ***

             23.00  ***
            -31.15  ***
    3.1567237E-02  ***

             24.00  ***
             -0.60  ***
    1.2512587E-05  ***

             25.00  ***
             31.25  ***
    2.1707776E-03  ***

             26.00  ***
             64.40  ***
              0.12  ***

             27.00  ***
             99.65  ***
              1.67  ***

             28.00  ***
            134.50  ***
              3.38  ***

             29.00  ***
            171.65  ***
             22.15  ***

             30.00  ***
            210.00  ***
             25.62  ***

             31.00  ***
            249.65  ***
             71.30  ***

             32.00  ***
            290.60  ***
             72.20  ***

             33.00  ***
            332.85  ***
             72.72  ***

             34.00  ***
            375.40  ***
             72.37  ***
```

```
       0.00  ***
    -450.00  ***

       1.00  ***
    -449.75  ***

       2.00  ***
    -447.40  ***

       3.00  ***
    -444.15  ***

       4.00  ***
    -438.00  ***

       5.00  ***
    -433.75  ***

       6.00  ***
    -425.00  ***

       7.00  ***
    -418.15  ***

       8.00  ***
    -407.40  ***

       9.00  ***
    -397.35  ***

      10.00  ***
    -385.00  ***

      11.00  ***
    -371.75  ***

      12.00  ***
    -355.40  ***

      13.00  ***
    -340.15  ***

      14.00  ***
    -322.60  ***

      15.00  ***
    -303.75  ***

      16.00  **
     282.60  ***

      17.00  ***
    -261.15  ***
```

Figure 9 (CONT.)

```
          18.00  ***
        -273.40  ***

          19.00  ***
        -215.35  ***

          20.00  ***
        -193.00  ***

          21.00  ***
        -157.35  ***

          22.00  ***
        -135.40  ***

          23.00  ***
        -105.15  ***

          24.00  ***
         -75.60  ***

          25.00  ***
         -43.75  ***
2.001832654-09  ***

          26.00  ***
         -10.60  ***
2.022515353-05  ***

          27.00  ***
          27.85  ***
7.787883553-04  ***

          28.00  ***
          59.60  ***
           3.27  ***

          29.00  ***
          95.65  ***
           1.61  ***

          30.00  ***
         135.00  ***
           5.72  ***
```

```
   31.00  ***
  174.65  ***
   21.67  ***

   32.00  ***
  215.60  ***
   23.45  ***

   33.00  ***
  257.85  ***
   31.27  ***

   34.00  ***
  301.40  ***
   38.32  ***

   35.00  ***
  346.25  ***
   73.32  ***

   36.00  ***
  392.40  ***
   76.72  ***
```

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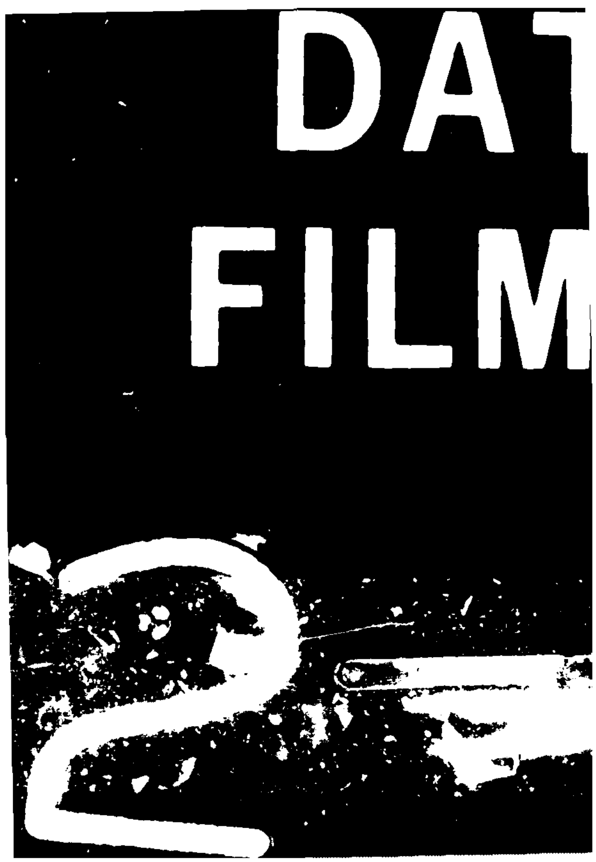
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